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South African mining equipment and specialist services: Technological capacity, export performance and policy

David Kaplan

Department of Economics, University of Cape Town, South Africa

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ABSTRACT

South Africa has developed a technologically sophisticated and globally competitive mining equipment and specialist services sector. The paper provides evidence for and measurement of technological competency and global competitiveness and a brief outline of why South Africa was successful in this regard. While there are significant prospects for future growth, there are, at the same time, a number of constraints and South Africa is becoming a less advantageous site for both production and for innovation. Current government policy does not address these constraints and the sector does not feature in government's vision for industrial or technology development. An alternative approach is proposed whereby the constraints are addressed and the companies supplying the mining sector that have sophisticated technological competencies are encouraged to spread "laterally" into new products and new global markets. By way of conclusion, the importance of this sector in developing countries where mining plays a major role is outlined.

Technological change in mining equipment and specialist services

There is a widespread perception that natural resource based activities, and mining in particular, are not the sites of significant technological change. Together with the purported long term decline in the prices of commodities relative to the prices of manufactures, low levels of technological change were the foundations for the Singer–Prebisch thesis in favour of a development path based on the development of manufacturing industry. Singer argued that "…they (natural resource based activities) do not provide the growing points for increased technological knowledge, urban education, the dynamism and resilience that goes with urban civilisation as well as direct Marshallian external economies." (Singer., 1950, p. 476).[1]

This perspective has enjoyed wide but not universal acceptance.[2] More recently, there has been a growing recognition that a number of factors are resulting in mining and mining related specialist services becoming increasingly technologically intensive. These factors include inter alia the growing utilisation of generic transformative technologies especially ICT; the reorganisation of the industry to allow for the growth of specialist mining services companies; the segmentation of markets; the intensification of technological challenges particularly as the industry has to meet stricter safety and environmental standards and to discover and exploit more marginal resources.

Marin et al. (2009, p. 9) provide a detailed discussion of the forces that are driving innovation in natural resource activities. They divide these forces into four categories:

- Market requirements—product segmentation; public opinion and environment.
- S&T advances—ICT and other new technology paradigms such as biotech. And nanotech.
- Market context—globalisation, outsourcing, environment and other regulations, government policy.
- Market volume—the intensification of traditional challenges, including the diminishing quality of resources.

This literature sees the centrality of technological progress in the development of the minerals industry as a relatively recent phenomenon, coinciding with the introduction of the ICT paradigm in the organisation of the global mining corporations (Marin et al., 2009; Upstill and Hall, 2006). However, at least in the case of South Africa, sophisticated technologies and developments in basic sciences such as chemistry were widely utilised in order to resolve critical problems in relation to local mining deposits for

E-mail address: david.kaplan@uct.ac.za

[1] Prebisch (1959) similarly argued that extractive industries provided fewer possibilities for technological progress than other sectors.

[2] For a contrary view see North (1955, p. 252), Viner (1952, p. 72) and more recently Wright and Czelusta (2007).

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almost a century. Moreover, while these technological capacities were initially based on imported skills, they were, at least in some important instances, rapidly localised in the early development of the Witwatersrand. For example, the development of the cyanide process in the 1890s "…led to an influx of metallurgical professionals from around the world and gave birth to one of the early professional societies in Johannesburg, the Chemical and Metallurgical Society or the 'Cyanide Club' as it was popularly known" (Pogue, 2006, p. 82).

The mining industry is often regarded as low technology because the conventional indicator employed to determine technological intensity is R&D expenditure as a percentage of turnover. However, much of the product development expenditure in this sector is not classified as R&D. The R&D measure when applied to the mining industry in aggregate also ignores the more technology intensive activities within mining such as exploration.

The sectors supplying the mining industry with equipment, intermediates and sophisticated services are the site of significant technological change. These supplier industries – here termed mining equipment and specialist services – employ sophisticated technologies and undertake considerable research although here too, research activities are often applied and incurred in relation to product development rather than formal R&D. Technological sophistication has been increasing rapidly, particularly as mining and metal processing firms have focused on operational competencies and have increasingly contracted out other activities to specialised suppliers. While South Africa has had a long standing and highly developed mining sector which has been the subject of considerable study, what has been barely recognised and not been the subject for any extensive research is that South Africa has also developed a very sophisticated mining equipment and specialist service sector.

Utilising a number of technology and trade data indicators, this paper explores the technological capacities and competitive position of South Africa's mining equipment and specialist services sector. The paper examines the sector and its future prospects. The paper proposes that government policy be directed at further developing this sector and encouraging companies that supply the mining sector and that have sophisticated technological competencies to spread those competencies "laterally" and engage in new activities and new markets. This case study has broader implications for technology and industrial policy in general and specifically for other countries where mining plays a major role in the economy.

Technology and trade data are supplemented by extensive firm visits and interviews. Interviews were conducted with senior management in dozen firms in the industry. Firms selected were across the size spectrum and they included both local (2/3) and foreign owned firms (1/3). In addition interviews were conducted with the Chamber of Mines, with two universities and with the industry export council—the South African Capital Equipment Export Council (SACEEC). The firm interviews focused on three issues—first, the technological competencies and competitive position of the firm; second, the constraints currently faced by the firm and how they were being addressed and finally, the future plans of the firm.

The rest of the paper is divided into six sections:

Section 2 provides evidence for and measures of the level of technological sophistication and competitiveness of mining equipment and specialist services sector in South Africa.

Section 3 provides a brief explanation for the development of the mining equipment and services sector in South Africa.

Section 4 outlines the future prospects for the sector with a focus on the key constraints.

Section 5 provides, in the light of the constraints outlined earlier, an examination of current government policies and proposes an alternative approach.

Section 6 briefly explores the broader implications of this study.

Technological capacity and export performance: evidence and measurement

Assessing the technological capacities of an industry and its distance from the global technology frontier is not a simple task. The most widely utilised measure is the number of patents registered abroad by locally registered companies. This measure is employed here. In addition to the number of foreign patents, measures are provided here of the quality of the patents. Since a significant share of the research work undertaken in this sector is product development, the extent to which South African firms have developed and introduced new technologically sophisticated products into the market is also outlined. A further measure is the extent to which South Africa provides a location for foreign firms to undertake research and product development. The final measure is the presence of local South African companies providing mining equipment and specialist services with a significant technological component in global markets.

In respect of measures of the competitiveness of the South African industry, export trade data are central but are supplemented by an examination of the balance of trade (exports–imports) and the degree of local value add.

Technological sophistication

Patents[3]

An examination of the patents taken out by South African companies, organisations and individuals at the United States Patent and Technology Office (USPTO) utilising 3-digit USPC classes, revealed a clear technological cluster which can broadly be termed "mining related technologies." The quantity and the quality dimensions of this cluster of mining related technology patents were assessed utilising 1976–2006 USPTO patent data.

The share of mining related patents in total South African patents was compared to the global average in order to construct an index of revealed comparative advantage in innovation (RCAI). But, in order to "go beyond the numbers," the quality of South African mining related patents was determined and then compared to mining related patents for three selected comparator countries that are widely acknowledged to be at the global technology frontier in mining—the United States of America, Canada and Australia.

Patent quantity

Mining-related technology patents make up a much larger share of South Africa's total patenting activity at the USPTO than for other comparator countries which have significant mining industries and are considered to be at the technology frontier (Table 1).

An index of South Africa's revealed comparative advantage in innovation (RCAI) analogous to the revealed comparative advantage in trade (RCAT) can be calculated. The RCAI is the number of South African mining related patents over the total number of all South African patents (4.5%), while the denominator is the analogous data for the number of global mining related patents over the total number of all global patents granted at the USPTO (0.54%). South Africa's RCAI for mining technologies is accordingly 4.5/0.54 viz. 8.4. This indicates that South Africa has a very significant global comparative advantage in mining related technology innovation. South Africa's RCAI is also higher than for

[3] The patent data were supplied by Lee Branstetter of Carnegie Mellon University for the World Bank project, Closing the Skills and Technology Gap in South Africa Kaplan et al. (2011, Annex).

Table 1
The number of patents and mining related patents at the USPTO 1976–2006; South Africa and Comparator Countries.
Source: United States Patent Office database, 1976–2006.

Country	All patents	Mining tech. patents	Share (%)
South Africa	3151	142	4.51
United States	1,587,915	7882	0.5
Australia	16,283	311	1.9
Canada	65,580	853	1.3
Global total/average	3,189,941	17,098	0.54

Note: A patent belongs to the "Mining Related Technologies" cluster if it belongs to one of the following 3-digit USPC classes: 299: mining or in situ disintegration of hard material; 051: abrasive tool making process, material, and composition; 023: chemistry: physical processes; 037: excavating; 075: specialized metallurgical processes; 172: Earth working.

other comparable countries that are technological leaders in mining related technology.

Patent quality

In order to assess the quality of patents, the average number of citations received by South African patents and the average number of truncation-corrected citations received by South Africa patents were compared relative to the same comparator countries. The number of citations is a proxy for the technological advance of the patent. The truncation–correction refers to the fact that it takes time for citations to arrive. Older patents will naturally have more citations than younger ones. A truncation–correction allows for a more "fair" comparison between samples of patents with different age distributions:

Two results are evident:

1. South African mining related patents receive significantly more citations than other South African patents. By contrast, for comparator countries, mining related patents receive fewer citations than other patents. By this measure, the values of South African mining patents are high by comparison with other South African patents.
2. South African patents in aggregate receive fewer citations than patents in the comparator countries. By contrast, South African mining patents receive more citations than patents of comparator countries. By this measure, the value of South African patents is higher than for comparator countries, other than the United States.

Utilising a matching methodology to randomly match each South African patent to a similar American, Canadian, or Australian patent – matching by application year and 3-digit USPC class – gives somewhat weaker results. Matching suggests that the average number of citations for a South African mining related patent is likely to be somewhat less than that of a similar Canadian or US patents. However, a South African mining related patent is more cited than that of an identical Australian patent (Table 2).

Further indications of advanced technological capacities

In addition to the patent data, there are three further indications of South Africa's significant technological capacities in mining equipment and specialist services.

First, the South Africa mining equipment and specialist services sector has attracted considerable foreign investment. Foreign investment is market seeking but also seeking to enhance product development activities. Several of the leading global TNCs in mining equipment and services have significant operations in South Africa and a number of these firms select South Africa as a preferred site in which to undertake research and particularly product development. Their South African subsidiaries utilise local know-how and support services in order to complement their overall research and product development activities. The South Africa operation also serves as a regional hub for their activities in the region with considerable capacities to address local technological challenges.

Table 2
The quality of patents and mining related patents at the USPTO, 1976–2006; South African and Comparator Countries.
Source: United States Patent Office database, 1976–2006.

All Countries	All patents	Mining related technology patents	Other patents
Citations received (not truncation corrected)			
South Africa	5.52	7.05	5.44
United States	8.52	6.99	8.53
Australia	5.39	4.15	5.41
Canada	6.60	4.70	6.72
Average	6.53	5.73	6.53
Citations received (truncation corrected)			
South Africa	7.95	9.01	7.90
United States	14.13	9.97	14.16
Australia	9.41	6.16	9.47
Canada	11.43	6.91	11.49
Average	10.73	8.01	10.76

Second, at the product level, South Africa is a world leader and first to market in a host of mining equipment and especially services. This illustrates the product development capacities of South African firms. These products have generally been designed and developed by local companies, while a few have been developed in collaboration with foreign partners. These locally developed products include physical products such as spirals for washing coal; mining pumps for deep level mines; hydropower equipment; tracked mining equipment; underground locomotives and ventilation equipment and services such as shaft sinking; prospecting; geological services and turnkey new mine design and operation services and many others. Many of these products entail considerable technological expertise and some require broad ranging technological capacities—the ability to deliver a turnkey mining or smelting operation for example. The "area" where South African expertise is particularly advanced and at the global frontier is in deep level mining and associated competencies—shaft sinking for example. South Africa's competitive position is weaker where large-scale economies are required. For example in so-called yellow metal products – such as mining and haulage vehicles – scale economies are critical and here large TNCs tend to dominate.

Finally, at the company level, there are a significant number of South African firms that compete effectively with global TNCs, in South Africa, in Africa and in other regions. A number of these companies are large by local standards but significantly smaller than the largest TNCs. There are also a significant numbers of medium and small sized companies. In the main, South African companies compete in market segments which are technologically sophisticated. South Africa is particularly well represented in drilling—5% of the companies operating globally in drilling are based in South Africa (Porter and Ramirez-Vallejo, 2010, p. 38).

Export performance[4]

Trade data are categorised by product rather than by customer. This makes it very difficult to determine precisely what is

[4] Trade data were compiled by Masuma Farooki of the Open University, United Kingdom.

Table 3
South Africa Mining Equipment Exports and Imports ($'000), 2005–2009.
Source: COMTRADE database.

Exports and Imports	2005	2006	2007	2008	2009
World exports	3,292,256	4,721,750	6,200,709	6,742,700	4,130,184
World imports	3,173,526	4,285,689	5,987,691	6,174,743	3,668,875
Trade balance	118,730	436,061	213,081	567,957	461,309
SSA exports	786,793	1,025,801	1,494, 146	1,935, 971	1,542,666
SSA imports	10,972	13,423	15,317	24,485	32,232
SSA share of total exports (%)	24	22	24	29	37

intended for the mining sector as opposed to any other markets. With regard to South Africa, the South African Capital Equipment Export Council (SACEC) has identified, at an 8 digit HS level which products within capital equipment would be destined for the mining sector. The data in this section are based on the SACEC categorisation.

Utilising the SACEC categorisation, mining equipment is one of the South Africa's largest exports constituting 8.5% of total South African exports in 2005–2009 and 55% of total capital equipment exports. South Africa's global export share of the SACEC categories over the same period averaged 0.9%. This compares with South Africa's share of all global exports of 0.4%. The RCA for mining equipment therefore is 2.25 (0.9/0.4) indicating a substantial South African comparative advantage in the export of mining equipment. There is also considerable export of mining services. Unfortunately, the services export data do not allow for mining services to be isolated. But, net export earnings are likely to be substantial and significantly positive.

For all capital equipments, South African imports exceed exports by a large margin. In 2008 and 2009, South Africa's imports of capital equipment were three times larger than exports. In respect of mining equipment, however, South Africa is a net exporter. In mining equipment, South Africa is running a negative trade balance with the rest of the world, but South Africa has a strong positive trade balance with Sub-Saharan Africa (SSA). The share of SSA in mining exports has been increasing, resulting in an increase in the positive overall trade balance (Table 3).

While there is no hard data to hand, all the evidence suggests that mining equipment exports have a high local value added—high compared to other exports such as autos for example (see below). The South African Capital Equipment Export Council estimates local content for mining equipment at approximately 90% (Interview).

An RCA well above 1, a positive trade balance and a high local value add all indicate that South Africa is highly competitive in this sector. Moreover, South African mining equipment and specialist services firms have a very strong presence in Africa, which is forecast to be a rapidly growing market. This has important policy implications (see below).

Conclusion

South Africa has significant technological capacity in mining equipment and services that is located at the global technological frontier. This is evidenced by a number of measures—a significant cluster of high value patents; South Africa's ability to attract TNCs to enhance and develop products locally; the ability of local firms to develop unique and leading-edge products and the presence of numerous local companies which compete in technologically sophisticated segments of the market and which have a global reach. In terms of trade, South Africa mining equipment and associated services constitute a very significant export with a high local content and a positive balance of trade and a strong presence in the most dynamic market—Africa.

A search of South African patents at the USPTO revealed no other significant cluster of high value patents. Similarly, in relation to the trade data, there is no other South African manufacturing sector with significant technological content that has substantial exports with a positive trade balance and high local value addition.

Why has South Africa developed an advanced mining equipment and services industry?

The development of specialist mining equipment and services is, in important part, a function of the size of the market. For standardised mining equipment such as haulers and trucks, which can be applied without any significant modification in any setting, production is scale intensive and specialisation is determined, in classical terms denoted by Adam Smith, by the overall size of the market. South Africa has no significant advantages of scale and is accordingly not well represented in this domain. For example, South Africa has only a very limited presence in so-called "yellow metal "areas – such as mining vehicles – where scale economies are critical. In these areas the large TNCs dominate.

However, many applications of mining technology are context specific. Here, the impact of the market on specialisation is very different. At one end of the spectrum, where the market consists of a single large purchaser, potential specialist suppliers will have no advantage over the development of the technology by the large firm in-house that can offset the transaction costs entailed in transferring and adapting the technology obtained from outside of the firm. There will consequently be no outsourcing to specialist suppliers. Moreover, because of the specific nature of the application there will be no advantage to the large firm becoming a supplier of the technology it has developed for application elsewhere.

By contrast, where the specialist suppliers can serve a large number of different firms, the fixed costs of technology development can be shared over a number of applications. If the technical knowledge is not entirely idiosyncratic, once developed, it can then be supplied to potential users at nominal additional cost.

Specialist technology suppliers in the mining sector are therefore likely to arise where there are large numbers of potential users. Where individual users are large, technology suppliers are likely to be more restricted. Thus, the growth of specialised technology suppliers to the mining industry depends on the market—but on the economies of scope rather than on the economies of scale.[5]

[5] Arora et al. (2001) following Bresnahan and Trajtenberg (1995), and Helpman and Trajtenberg (1998) develop a similar argument in relation to General Purpose Technologies (GPT). Moreover, their model shows that as the

South Africa has a highly diversified mining industry with many mines spread over a wide variety of minerals—gold, platinum, coal, diamonds, manganese, chromium, copper and others. There are therefore a large number of potential customers for specialist suppliers of mining equipment and services. Significant economies of scope provided the foundation for the development of a diversified array of specialist suppliers of mining equipment and services.

Two further factors gave additional impetus.

First, the exploitation of South African mineral deposits presented very demanding and often unique technological challenges. This was most evident in respect of gold which had to be mined in hard rock and at far deeper levels than anywhere else. But, other major South African metals presented significant location specific challenges—coal and platinum, in particular. Coal in South Africa is very abundant, but almost all of it is of low quality. Platinum was prevalent but found in a form that could not be exploited by known methods. South Africa was able to develop coal and platinum metallurgy that allowed what were hitherto unprofitable deposits to be profitably mined. There were many spin-off capacities. South African coal had to be washed to remove impurities. This led to extensive development in spirals for washing—a product which is now applied in a number of new areas such as tar sands and in which South Africa leads the world. "We made it work because we had difficult coals. (Interview; leading export company) There were similarly spin-off products in respect of platinum.[6]

Second, the search for "home-grown" solutions was spurred by South Africa's economic isolation and very limited foreign investment, particularly during the latter years of the apartheid regime. The reduced presence of foreign technology suppliers, allowed for local firms to dominate the domestic market.

Local firms were accordingly strongly focused on the domestic market and exports were very limited. However, with the demise of apartheid, these firms were able to move into new export markets and they did so rapidly. This was strongly facilitated by the internationalisation of South African mining firms as they expanded their activities outside of South Africa, particularly but not exclusively in gold mining. Given their long-standing relations with local firms, South African mining firms tended to favour these same suppliers to service their activities abroad.

The contrast with Chile is apposite. In sharp contrast with South Africa, the mining industry in Chile consisted of a few very large firms. Mining in Chile accordingly had economies of scale but lacked economies of scope. In addition, mining in Chile was virtually confined to the exploitation of a few very high grade and very profitable copper deposits. The challenge and the incentive to enhance technology and hence to engage specialist technology based suppliers were accordingly much reduced. Moreover, the large Chilean state-owned mining firm Codelco remained confined to Chile. Limited economies of scope; the high grade of ore and the confining of the dominant state mining company to the domestic market have curtailed the opportunities for the growth of specialist equipment and services suppliers to the Chilean mining industry. As a result, the development of a local mining equipment and specialist services sector has been much more limited in Chile than in South Africa (Urzua, 2007, pp. 5–6).

Government policy has also played an important role. In various ways, and for complex reasons, government sought to enhance technological capacities. This process of encouraging the development of local technological capabilities was begun very early in South Africa with a strong emphasis on the needs of the mining industry (Pogue, 2006, p. 7).

Government support was principally directed at the provision of education and training, including high level skills. Support for publicly funded research institutes and universities was also very significant. As outlined below, this support has been significantly decreased over the last two decades.

A further important factor enhancing the development of the industry has been the development of a geographic cluster and attendant supporting institutions. While the industry is geographically fairly widely distributed much of the mining equipment industry is located on the East Rand, principally in Ekurhuleni, and largely in Farrramere. Utilising a database of 678 companies, the South African mining inputs cluster has the following characteristics[7]:

- Ownership—33% of firms are foreign; 67% local. Foreign firms are specialist consultants or Original Equipment Manufacturers (OEMs).
- Employment—95,000. Average number of employees per firm - 239.
- Seventeen large firms account for almost 60% of employment. The majority of firms are either subsidiaries or private companies. Only seven firms are listed on the Johannesburg Stock Exchange.

Imported items are generally medium to high tech component type goods. Other inputs are supplied locally resulting in high local value addition.

The local Further Education and Training (FET) College provides training in skills that are needed by the industry. A total of 112 firms constitute the South African Capital Equipment Export Council (SACEEC). This constitutes a significant share by number of exporting firms and the overwhelming share of exports by value. The SACEEC supports exporting and promotes the capital equipment industry generally—with most of its activity focused on mining equipment. The SACEEC also works with Government on an ongoing basis to ensure that policies are supportive of industry development in general, and of exports, in particular (interviews).

Future prospects and current constraints

The short-medium term prospects for mining equipment and specialist services appear to be promising. High commodity prices are underpinning growing investments in mining. A large share of the world's unexploited mineral wealth is in Africa.[8] South African based mining companies are, as noted, particularly strongly represented in the region and predicted strong growth in mining investment in Africa will be beneficial to South African exporters of mining equipment and services.

However, company interviews suggest a less promising future. Interviews with local mining equipment and services firms identified three major constraints on future growth—skill shortages and inadequate training; deteriorating public research and linkages with tertiary institutions and limited access to finance.

(*footnote continued*)
potential number of applications increases, specialist suppliers will invest more in reducing the costs entailed in transferring and adapting the technology to new applications. This will further enhance specialisation and the division of labour.

[6] "Given the unique geological and metallurgical challenges associated with extracting and processing PGM (platinum group metals) ore bodies, South African suppliers have become world leaders in areas such as hydropower, ultra-low profile trackless equipment, smelting and refining equipment, shaft sinking, ventilation and cooling services, tailings treatment, engineering procurement and construction management services, contract mining and process control" (Lydall, 2009, p. 119).

[7] The data are from Walker and Minnitt (2006, pp. 13–17).

[8] The standard estimate is that Africa hosts about 30% of total global mineral reserves (African Development Bank, 2010, p. 1).

Skill shortages

The World Bank Investment Climate Survey data provide evidence of the skills constraint for firms in the capital goods sector. In 2003, exporters and non-exporters as well as foreign owned and domestic firms in the sector in cited skills shortage as the top constraint. In 2007, crime was identified as the top constraint followed by skills shortages (Goldberg et al., 2011, p. 76). More directly pertinent to mining equipment, in a recent survey, 50% of the 45 firms supplying goods and services to the platinum group mining (PMG) sector reported the shortage of engineering and technical skills in South Africa as "…the main obstacle to future growth and dynamism in the PGM industry and 90% feel it is an important determinant for firm-level competitiveness (Lydall, 2009, p. 117).

Most of the firms interviewed confirmed that the lack of skills was a key constraint on their further development. Skill shortages were said to be particularly acute at the managerial, engineering, artisanal and technical levels such as welders and boilermakers.

One factor that has exacerbated the skills shortage is the migration of skilled workers abroad. Local firms complained of aggressive recruiting on the part of competitor firms, especially in Australia, who have been particularly successful at recruiting skilled South Africans. Local firms who attempt to respond to the shortage by recruiting abroad complain that they have major problems in securing the necessary work permits for expatriate labour. This complaint was voiced by locally owned and particularly foreign owned firms.

Training is fairly widespread in the industry. However, worker training is poorly provisioned. The system designed to oversee and provide incentives for firm level training, the Sector Education Training Authorities (SETAs) are widely regarded by firms in this industry as ineffective and the system as inflexible (Interviews). Training is particularly deficient in respect of artisans and technicians. In regard to higher levels skills, firms were of the view that the number and quality of engineers and other related skills is on the decline. The Chamber of Mines described training at the universities as "pitiful" (Interviews).

In the firm interviews, senior managers pointed to the skills shortage as the major factor behind local companies are locating some of their operations abroad. In particular, firms are finding it advantageous to shift their more labour intensive manufacturing operations outside of South Africa—notably to China. As one example, one of the largest South African operations now fabricates 20% of needed capital equipment in China whereas previously equipment was produced exclusively in South Africa (Interview). A number of firms, particularly the larger operations that can manage extensive outsourcing operations, are predicting that their sourcing of products from outside of South Africa will increase rapidly (Interviews).

Moreover, it is not only manufacturing operations that are likely to be increasingly relocated outside of South Africa, the same trend is evident with respect to design and development work. A shortage of high level skills has resulted in a number of the major mining companies locating more of their research and development activities abroad. One of the largest South African operations undertaking extensive design and development has decided to develop a new centre abroad rather than in South Africa as a direct response to the difficulties of securing the right skills. The firm predicts that within a few years it will have its main design centre in Australia. The country favoured is almost invariably Australia; with the main attraction being first the availability of highly skilled labour and second the linkages to well-funded research centres.

Declining industry-research institutions linkages

Linkages with the science councils are limited and declining. This is true particularly in relation to mining, but also with regard to metallurgy and metal refining. There is a widespread view, both in the industry and in the science councils that, while some research capacity remains in the science councils, there has been a clear reduction in funding for research and a consequent deterioration over time. Most notably, South Africa's largest research institution, the CSIR, which previously had large programmes in relation to mining, principally in trackless mining and rock engineering, has hardly any research capacity remaining.[9] MINTEK which focuses on minerals processing and metallurgical engineering has significant capacity, but it too is said to be in decline (Interviews) The Council for Geoscience is similarly said to be experiencing difficulties, particularly in securing skilled staff.

In terms of university based research, activity is also depleted. While there is certainly some capacity and some of that is widely recognized as world class, commensurate with the decline in training, there has been a decline in research capacity. Very few of the firms that were interviewed engaged with the universities. Where there was some engagement, this was said to have been steadily declining and to be currently very limited (Interviews).

The deterioration in publicly funded research for mining, metallurgy and related activities in South Africa in both the science councils and in the universities has resulted in firms making much more use of privately funded research. There has been a significant growth in local research consultancies that serve the industry, undertaking research or providing specialist consultancy services. Deterioration in publicly funded research has also led local firms to increasingly engage with publicly funded research institutions and universities located abroad, particularly in Australia.

By contrast with South Africa, the Australian government provides significant and increasing support in regard to mining and mining related research. Mining related research is more lavishly supported and embedded in an intimate relationship between government and industry. [10]

The contrast between the support for technology on the part of the South African and Australian governments is exemplified in relation to automated mining. The CSIR Miningtek division earlier led global research in this area. However, the programme has been progressively downscaled and finally abandoned. By contrast, in Australia, the publicly funded Australian Centre for Field Robotics (ACFR) in 2007 commissioned a major new Centre for Mine Automation. Mining firms, like Rio Tinto, have also committed significant resources to this centre whose aim is to develop a fully autonomous, remotely operated mine (Department of Innovation Industry Science and Research, 2011, pp. 10–11).

As a result, Australia is increasingly becoming the location of choice for research and development on the part of South African firms and indeed of South Africans themselves. This was not always so. As one interviewee put it—"In the 1980s all the clever stuff was in South Africa. This was the magnet. We attracted people from all over the world. Now the magnet is in Australia and we are losing our people, our talent and even our companies to them" (Interview).

Access to finance

A number of the firms interviewed complained that export finance were limited. This inhibits exports and firms access to the global knowledge pool. The SACEEC which works with the

[9] A recent report noted that mining research in the CSIR "….has virtually disappeared." (ANC, 2012, p. 6).

[10] Australia has extensive networking and collaboration between companies and with publicly funded research. This has been described as a "dynamic web" (Dodgson and Vandermark, 2000). See also Upstill and Hall (2006).

government on an ongoing basis to ensure that generic policies and priorities are aligned with the sector development strategy regards this lack of export finance as particularly injurious to new exporters who are unable to accept large export contracts due to the lack of adequate finance. Finance is often not available and where it is, it is said to be very costly.

New entrants are also constrained by the lack of venture capital available to finance technology-based start-ups. Potential new entrants cannot find the finance that they require to commercialize research or seed funds required to launch new products.

Investments into new mining projects in South Africa have been limited. For a variety of reasons, related principally to policy over mineral rights, but also severe infrastructural bottlenecks and lack of local finance for new mines on the part of smaller companies, investment in the mining industry actually fell during the commodities boom. The output of gold, in particular, has been declining steadily and this is likely to continue. The "demanding clients" that have underpinned the growth of local capacities in mining equipment, the large-scale mining investments, remain but are declining in number.

Conclusion

South Africa lacks the supply of skills, the institutional and policy supports in relation to research and product development, the finance and the continued growth of sophisticated and demanding clients that will be necessary to ensure high levels of future growth.

The current success of the South African mining equipment and related activities and services rests in an earlier period of expansion of the mining industry and of elaborate public support for research and training. The companies and the people who were so nurtured and supported are now exporting globally and undertaking technological advance at the global frontier. However, there are clear signs that this will not be sustained in the future. Skill shortages, declining support for research and development, declining investment on the part of local clients and a general lack of institutional and policy support are likely to severely curtail future prospects.

Current government policy and an alternative approach

Current government policy does little to mitigate any of the constraints that have been identified as inhibiting the further development of the mining equipment and specialist service sector. The post-apartheid government has had its attention and its hopes for economic advancement firmly fixed on the development of new manufacturing industries and progress in advanced sciences such as biotechnology and nanotechnology. Indeed, the potential for growth of this sector and its potential contribution to broader economic development is almost entirely unrecognised.

1.1. Current policy

The Department of Science and Technology (DST) has a 10-year innovation plan which identifies a number of areas for support (Department of Science and Technology (DST), 2008). These areas include space science, pharmaceuticals, energy, climate change, biotechnology and human and social dynamics. These are all science intensive areas. No consideration is given to the mining and specialist services sector despite its high knowledge content. The Department of Trade and Industry (DTI) (2007) has formulated an ambitious industrial policy. The Industrial Policy Action Plan (IPAP) entails sector support programmes for a wide range of industrial sectors (Department of Trade and Industry (DTI), 2010). One of the sectors identified is capital equipment. However, capital equipment is "lumped" together with metal fabrication and transport equipment (Department of Trade and Industry (DTI), 2010, pp. 36–42). Mining equipment and specialist services, despite being by far the most competitive and export-oriented part of the capital goods sector, receives no particular or special attention. Indeed, the main thrust of the support offered by IPAP for capital equipment is through government procurement policies i.e. focused on the domestic market rather than exports and of little concern to the suppliers of mining equipment.[11]

There is currently a disconnect between South Africa's technology or innovation policy and its industrial policy—innovation policy is focused on frontier high-science activities and industrial policy concerned with supporting a very wide and disparate range of industrial activities. Mining equipment and specialist services are currently well "below the radar" of both technology and industrial policy.[12]

An alternative approach

We saw earlier that South African mining equipment and specialist service firms are located at the global technological frontier. The "knowledge intensity" of this industry is high and indeed, since this is the only substantial sector where a major cluster of South Africa firms has been identified as having significant expertise located at the global technology frontier, possibly uniquely high.

Any expansion in output in mining equipment and specialist services is accordingly accompanied by a greater increase in "knowledge content" as compared to an equivalent expansion in output in other sectors which have a lower "knowledge content". Output expansion in mining and specialist services will be accompanied by greater learning, innovation and associated externalities as compared with output expansion in other sectors.

Moreover, "knowledge content" is generally "embodied" in distinctive products and intellectual property, such as patents, posing entry barriers for potential competitors. This provides a more sustainable basis for future earnings.

Two other factors underpin the case for support for this sector. First, for industrialising countries, manufactured exports are heavily concentrated in a few product and market combinations (Easterly et al., 2009). This concentration underlies the need to ensure that any sector support favours those sectors that have a strong presence and some clear advantages in relation to markets where there is strong likelihood of growth. South African mining equipment and services have both a strong presence and distinctive advantages in relation to a market where there are clear prospects for growth, namely mining activity in Africa.

Second, this sector is characterised by a large number and variety of firms, institutional supports and a clustering of activities. As we have seen, this results in very high local value addition. The impact on overall economic growth of any gain in output or productivity in this sector will accordingly be correspondingly high.

For all these reasons, the mining equipment and specialist services sector merits recognition and specific sectoral support. In

[11] "Leveraging the public infrastructure programme presents the single largest opportunity to stimulate the industry through reducing import leakage of the capital and operational expenditure programmes of the State Owned Enterprises (SOE) and all spheres of government" (DTI, 2010, p. 36).

[12] The National Industrial Policy Framework which sets out the broad framework for government's industrial policy contains the only explicit recognition of mining "goods" and its technological capacities. "…there are areas in which South Africa is developing its own proprietary technologies, such as mining goods and nuclear energy" (DTI, 2007, p. 26). However, this is not translated into any explicit policy. South Africa's nuclear energy programme has since been scrapped.

order to enhance the competiveness of the sector, the critical constraints that face this sector must be addressed—particularly in relation to skills and training; public support for research; linkages to the universities and science councils and access to finance. This is particularly urgent in the light of rising competition in relation to manufacturing (principally from the Far East) and a rising challenge in relation to knowledge and innovation (principally from Australia).

But, there is a further policy challenge—namely to support the spread of these technologies and companies into new non-mining related products and markets. To some extent this is already happening. The success of mining-related capital equipment and service exports is, for example, linked to the export of South African engineering and project management capabilities more broadly.

However, there are knowledge and information gaps whereby firms fail to see the potential application outside of known areas and customers and there are costs and risks of new product and new market development. The fact that firms who move into new areas take risks while much of the benefit of success falls to follower firms (second movers) constitutes a market failure that potentially provides a "space" for public policy. The South African capital equipment "sector" is highly organised and cohesive with an active export association. This allows for government to investigate, in close consultation with the industry and export association, how firms might be encouraged to apply their technological capacities to new products and new markets.

The spread of frontier level technologies outside the mining sector into new products and new markets – the lateral movement of existent technological competencies – should be encouraged. One possible direct mechanism for doing this would be the creation of a "challenge fund". The "challenge fund" would support firms that utilise their existing technological capacities in relation to mining in order to adapt or develop new products and enter into new markets outside of the mining industry. The challenge fund would meet part of the costs incurred by the firm. Qualifying items would be public goods such as training, infrastructure and market entry. Applications for support should be judged on a competitive basis and by an arms-length group composed principally of persons with business know how and knowledge of the industry.

The existence of such a challenge fund would, in and of itself, constitute a signalling device to firms in the industry as to government's commitment to enhance new product and new market development.

Finland is the paradigmatic example of a successful diversification from natural resource based industries. Government adopted a systems approach to industrial and technology policies emphasising linkages and spillovers between industries. Linkages as between research organizations, universities, firms and industries in relation to knowledge production were promoted and policy was formulated through public–private partnerships involving economic research organizations, industry federations and firms (Dahlman et al., 2006, p. 8).

While the precise policy modalities will differ, there is much to learn from the Finnish experience. The emphasis on diversification through promoting linkages and spillovers between industries; a systemic approach to an integrated industrial and technology policy and the development of policy in close collaboration with the firms, industry associations and research organisations provides a guideline for effecting the lateral movement of technological competencies in other country contexts.

Broader implications for policy and development

In many developing countries, particularly in Africa, mining activities constitute the largest source of internal demand for a range of goods and services. With increasing investment, arising from higher commodity prices, the scale of demand is likely to increase. Since mining is highly location specific what can be called "applied competencies" have to be developed with reference to particular deposits and hence on often "on site." As outlined earlier, economies of scope and the extent and distinctiveness of local conditions and challenges will exert an important influence on the extent of local demand and the emergence of specialised equipment and service suppliers.

Mining equipment and especially specialist mining services which generally have lower barriers to entry often develop at very early stages, even in low income countries. These firms tend to cluster and can constitute a significant source of local competencies and potential exports. The case of Mongolia is apposite. A recent report has outlined the development of the Mongolian mining services sector. While the sector is small, comprising only 33 companies clustered in Ulaanbaatar, there has been a significant increase in technological competency and in exports to the region. Regional demand is anticipated to grow strongly and the report accordingly recommends a series of cluster initiatives and policies to enhance technological competency and export growth (Porter and Ramirez-Vallejo, 2010).

Government has an important influence. One thrust of government policy could be to build backward local linkages from mining. The large mining TNCs are increasingly and publicly committed to enhancing such linkages. There is therefore some common ground and policies scan now be developed in collaboration with the mining companies. Particular attention should be paid to those goods and services such as engineering services which are locally comparatively technologically intensive and which have potential widespread application outside of mining. Support for technological upgrading will be required to allow local suppliers of goods and services to the mining industry enhance their technological capacities. Optimal policy requires that industrial and technology policy are accordingly aligned and complementary.

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